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Monetary Policy Conduct Based on Nonlinear Taylor Rule: Evidence from South Africa

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Abstract

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This paper analyses the applicability of a nonlinear Taylor rule in characterizing the monetary policy behavior of the South African Reserve Bank, using a logistic smooth transition regression approach. Using quarterly data from 1976 to 2008 to analyze the movement of the nominal short term interest rate for the South African Reserve Bank, we find that a nonlinear Taylor rule holds. On the contrary, some studies find that the South African Reserve Bank behavior can be described by a linear Taylor rule, but only because these studies removed the structural break which coincided with the Asian crises and estimated two different Taylor rules. Our study does not remove the structural break as it is an anomaly path, thus it uses the entire sampling period. Our results go counter to the above mentioned findings. In fact, our results are consistent with the international findings on the European Central Bank and the Bank of England that the nonlinear Taylor rule holds.

Keywords: Taylor rule, smooth transition regression model, interest rate reaction functions, nonlinearity

JEL Classification: C22, E17, E43, E52, E58

1. Introduction

Many studies have tested the Taylor rule for monetary policy conduct internationally. However, there have been few studies carried out for emerging markets. Studies undertaken by Petersen (2007), Castro (2008) and Cukierman (2004) mainly focus on nonlinear models in developed economies such as the US and UK. Notably, there is a gap within emerging markets in particular South Africa that presents an opportunity for the utilization of nonlinear models to characterize the behaviour of the Reserve Bank using interest rate functions. Interest rate reaction functions have normally been formulated using the linear Taylor rule. This could be attributed to the notion that linear models on several cases are perceived to render reasonable approximations to the exact nonlinear interactions.

The Taylor rule spells out that the interest rate adjusts in accordance to the deviation of inflation from its target and real output from potential output. It also assumes in the US for instance, the federal funds rate is raised by 1.5 percentage points for each 1 percentage point increase in inflation (Taylor 1993). Further, an increase in the interest rate of that magnitude would raise real interest rates and help cool off the economy, thus reducing inflationary pressures. According to Taylor (1993), the rule also assumes that interest rates are reduced by 0.5 percentage point for each percentage point decline in real GDP below its potential. Such a reduction in the interest rate helps to mitigate a (growth cycle) recession and maintain price stability.

Recent findings by Castro (2008) point that there has been an increase in the usage of nonlinear model as central banks tend to have asymmetric preferences in their loss functions implying that weights assigned to negative and positive output gap and inflation could be different. With, the current dominance of financial instability (i.e. financial crises) the central bank tends to behave differently in the manner it adjusts its reaction functions to respond to economic booms and slumps. Furthermore, Castro (2008) shows that the failure by the US and UK to incorporate financial conditions in their monetary policy rule could have exposed them to the current financial crises.

The behavior of interest rate has been characterized by the use of smooth transition regression models, for example logistic smooth transition regression. This theoretical approach has been used extensively by Terasvirta and Anderson (1992). In their study, they argue that the Smooth Transition Regression model could be regarded as a regime switching model, whereby the transition from one regime to another occurs smoothly. For instance, from a low to high inflation regime (see e.g. Terasvirta (2006), and Castro (2008)) and Petersen (2007) argues that STR model is capable of justifying why and when the central bank adjusts its policy rule. The model requires the identification of a transition variable. This variable will indicate a point where a change from a low regime to a high regime takes place. This point of inflection is referred to as the threshold level. In this paper, we have used the grid search method to identify threshold levels as well as the speed of adjustment of the transition variable.

This paper contributes to current monetary debates through identifying how quickly interest rates move from a low to a high interest rate regime, estimating in the context of emerging markets. In addition, it identifies as well as shows the existence of threshold level of the transition variable for decision making. Further, we also evaluate the performance of linear and nonlinear models in providing accurate forecasts. To undertake this evaluation, we use the Diebold- Mariano (DM) and the Sign test to determine the forecasting performance of the linear and nonlinear models. The DM test allows for the evaluation of the performance of two models in terms of their ability to accurately predict. We find that linear models perform better over long horizons compared to nonlinear models. This shows the importance of nonlinear models over the short run period in describing how differently the central bank responds to positive as opposed to negative inflation or output gap to drive them towards the required targets.

The rest of the paper is organized as follows: Section 2 presents the literature. Section 3 describes the methodology applied. Section 4 outlines the data. Section 5 presents the results and discussion. Section 6 conducts forecasting and Section 7 concludes.

2. The Literature

This section reviews literature on linear Taylor rule and goes further to discuss the nonlinear Taylor rule. The Taylor rule stipulates how the central bank should adjust the nominal interest rates according to the output gap[i] and inflation rate. The original Taylor rule assumes that the response of interest rates to economic conditions is linear and time invariant.

Taylor (1993) finds that the representative policy rule accurately traces actual monetary policy in the United States. It appears an interest rate function with positive weights on the inflation rate and output gap is favored in nearly all countries. Equation (1) indicates that the central bank raises its short term interest rate when the inflation rate exceeds the target level or when output gap is positive. Similarly, Bec et al (2000) note that the nominal interest rates can be regarded as automatic stabilizers as they enable the central bank to meet its target levels. Furthermore, the Taylor rule is useful as it provides an analytical framework which helps central banks in their decision making process. However, Taylor (1993) cautions central banks not to blindly implement the Taylor rule but to use their discretion in applying it, depending on the different situations that prevail.

The original Taylor rule does not incorporate the effects of the exchange rate which plays an important role in shaping the environment, as it was formulated for a closed economy. However, this paper intends to modify the original Taylor rule by including the real effective exchange rate term as an additional variable on South Africa, an open economy. The inclusion of an additional term will enable us to analyze how the interest rate responds to real exchange rate changes. Similarly, Taylor (2000) points out that there exist a relationship between interest rate and the exchange rate through capital markets.

2.1 Problems with Linear Taylor Rules

Empirical literature outlines the problems associated with the original Taylor rule. Firstly, the Taylor rule mainly depends on estimated variables (i.e. output gap and real interest

[i] Output gap can be defined as the amount of actual output by which it exceeds (falls short) potential output.

rates) that are difficult to measure in reality though they are robust conceptually. Secondly, Adema (2003) points out that it is problematic to measure an accurate level of the equilibrium real interest as this variable tends to vary over time. In addition, the original Taylor rule has been criticized for its dependence on ex post data [ii]and the output gap data is unknown with precision in reality unless possibly some years later. Thirdly, it is difficult to identify the most appropriate measure of potential output which is used in the calculation of the output gap. In fact, output estimates are likely to vary over time due to revision of data.

Research studies reveal that some authors have challenged the assumptions underpinning linear models such as the existence of a quadratic loss function. Woglom (2003) points out that the estimation of the original Taylor rule for the US Fed did not incorporate the interest rate smoothing term though nowadays different central banks include the lagged interest rate to show their interest rate smoothing preferences. Further, the original Taylor rule fails to incorporate the effects of the exchange rate which plays an important role in economic development. Lastly, Olmedo (2002) has questioned these assumptions on the basis that policymakers will not incorporate the state of business cycles when conducting monetary policy. In fact, he claims that the behavior of the central bank over the business cycle is asymmetric.

2.2 Reasons Justifying Nonlinear Taylor Rule

A central bank may engage in a nonlinear Taylor rule depending on whether its loss function is symmetric or asymmetric. Firstly, a nonlinear rule is appropriate to use when there is an asymmetric loss function in which different weights are assigned on positive and negative inflation and output gaps. Secondly, if the tradeoff between inflation and the output gap show signs of nonlinearities, using a linear model will give misleading results that will impart a bias to inflation. As a result, systematic mistakes in monetary policy may be encountered by using linear models.

[ii] This data could be different from the actual data available when the central bank set the policy rate.

Thirdly, empirical studies show that on average nonlinear models tend to outperform the simple linear specification in terms of its ability to track the actual interest rate. Yet, there is less literature on nonlinear Taylor models as Castro (2008) points out that only recent studies took into account asymmetries or nonlinearities in the analysis of monetary policy. Nonetheless, in some countries (e.g. United Kingdom) Castro (2008) indicates that the linear Taylor rule alone appears to have failed to explain the interest rate setting behavior.

Furthermore, Taylor (2006) suggests that although nonlinearities in the Taylor rule can result from either nonlinearity in the macroeconomic structure of an economy or asymmetry in the central bank's preferences, it is highly likely that both the presence and the interaction of these in the economy will amplify the degree of nonlinearity in the policy rule. Lastly, Cukierman (2004) argues that asymmetric central bank objectives lead to nonlinear policy rules even if the economic structure is linear.

2.3 Causes of Asymmetry

A nonlinear interest rate reaction function may result from asymmetry in the central bank's preferences pertaining to the weight assigned to deviation of inflation from target and real GDP from potential output. Furthermore, different arguments have been brought forth with regard to the sources of asymmetry in Central bank behavior. For instance, Olmedo (2002) suggests that asymmetry may arise due to the fact that monetary authorities are to some extent under political pressure since they are accountable to elected political officials for their decisions. In fact, Cukierman (2003) indicates that the central bank may be more averse to recessions as opposed to expansions. Similarly, Blinder (2000) argues that in some instances central banks succumb to political heat when it tightens pre-emptively to avoid higher inflation as opposed to when it eases pre-emptively to avoid higher unemployment.

In Bruinshoofd and Candelon (2004), asymmetry could arise due to different phases of the business cycle, thus whether there is an economic expansion or contraction. Therefore, during an expansionary phase, monetary authorities may be aggressive on inflation, whereas the stabilization of output receives a larger weight in downturns. However, according to Olmedo (2002) asymmetry may arise due to uncertainty in the effects of monetary policy on the economy that leads the central banker to be more cautious.

2.4 Evidence on Nonlinear Taylor Rule

In a recent study, Petersen (2007) intends to determine whether the Federal Reserve adjusts its policy rule according to a threshold level of inflation or output gap. Furthermore, he estimates the smooth transition regression model using data between 1960.1-2005.12 and his study attempts to estimate nonlinearities in the Taylor rule using monthly data for the period between 1960.1- 2005.12. He finds that the Federal Reserve switched from a linear model in the period 1960-1979 to a nonlinear threshold type model over the period 1985-2005. Petersen (2007) concluded that the Federal Reserve Bank changed its short term interest rate once inflation (transition variable) reaches a certain threshold. The research used inflation rate and output gap as explanatory variables only in a nonlinear Taylor rule equation. We add the real effective exchange rate and interest rate smoothing term in this study, following Ball(1999) suggestion that the Taylor rule for open economies are adjusted to incorporate the real exchange rate.

Castro (2008) analyses whether the central banks also target financial variables and assets prices information, in addition to inflation and output gap targets. Furthermore, he analyzes whether the central banks follow a linear or nonlinear Taylor rule. His study uses monthly data for three central banks namely, the United States Federal Reserve (Fed), the Bank of England (BOE) and the European Central Bank (ECB). Using a smooth transition regression model to estimate nonlinearities in the Taylor rule, the results show that only the federal reserve of the United States appears to have followed a linear Taylor rule. On the contrary, the Bank of England and the European Central Bank follow a nonlinear Taylor rule.

3. Methodology

In this section, I present the methodology used to estimate nonlinear Taylor rule. Firstly, I will show how one moves from linear to nonlinear model. For our study, we will use the following linear Taylor rule specifications namely, the backward looking rules, forward looking rule and hybrid rule.

Taylor (1993) put forward the following rule to characterize the implementation of monetary policy in the US:

$$i_t^* = r + \pi_t + \emptyset(\pi_t - \pi^*) + \beta y_t \tag{1}$$

where i_t^* is the target short term interest rate, r is the long run equilibrium real interest rate, π_t is the inflation rate, π^* is the target inflation rate and y_t is the measure of the output gap. In addition, $\emptyset$ indicates the sensitivity of interest rate policy to deviations in inflation from target and β indicates the sensitivity of interest rate to output gap. The coefficients of inflation rate and output gap are expected to have positive signs. If inflation rate or output gap increases the central bank will respond by raising interest rate.

A variant of Taylor rule by Woglom (2003) makes use of backward looking Taylor rule. This rule illustrates how the nominal interest rate relates to lagged values of interest rates, inflation rate, output gap and the real effective exchange rate. Using quarterly data, Woglom (2003) estimates the Taylor rule for South Africa during the pre and post inflation targeting periods to determine whether the adoption of inflation targeting policy has affected monetary policy. He focuses on acquiring information pertaining to whether inflation targeting affected the conduct of monetary policy and whether inflation targeting has improved the transparency and predictability of monetary policy. He finds that South Africa's monetary policy can be characterized by an implicit Taylor rule and his results show estimated coefficients with significant variables and expected signs. However, the real exchange rate plays a less significant role in monetary policy formulation.

The backward looking version of the Taylor rule as identified by Woglom (2003) can be illustrated as follows:

$$i_t^* = \alpha + \theta\pi_{t-1} + \beta y_{t-1} + \gamma q_{t-1} + e_t \tag{2}$$

where $\alpha = r - \emptyset\pi^*$ and $\theta = 1 + \emptyset$, π_{t-1} represents the lagged value of inflation from its target value and y_{t-1} is the lagged value of output gap and q_{t-1} is the lagged value of real effective exchange rate. Equation (2) indicates that the interest rate responds to the lagged inflation rate, output and real effective exchange rate. In essence, for a backward-looking Taylor rule, monetary authorities look at the previous values of inflation and economic growth to formulate monetary policy. However, the backward looking Taylor rule has been criticized for its inability to predict the future state of the economy with current inflation and output gap.

Clarida et al (1998) use the Generalized Methods of Moments (GMM) to estimate a forward looking rule for the United States during the post war period. It appears they focused their attention on the interest rate policy related to the period before and after the appointment of Paul Volcker as the Federal Reserve chairman. This has been done to indicate the changes in the actions of the Federal Reserve Bank over the post war period in response to changes in macroeconomic variables. Using quarterly time series data with sampling period ranging from 1960 to 2006, they find disparities in the implementation of monetary policy during the pre and post appointment of Volcker as the chairman of the Federal Reserve. Their results have expected signs and are all significant. Further it appears there has been a stronger anti-inflationary stance during the Volcker era (the post 1979) as real rates have been raised in anticipation of inflation rate increases.

The normal form for these forward looking regressions as identified by Qin and Enders (2008) is as follows:

$$i_t^* = \alpha + \theta E_t\pi_{t+1} + \beta E_t y_{t+1} + \gamma E_t q_{t+1}, \tag{3}$$

where $E_t\pi_{t+1}$ denotes the forecast of inflation between periods t and $t+1$; $E_t y_{t+1}$ represents output gap forecasts and $E_t q_{t+1}$ is a measure of the real effective exchange rate between periods t and $t+1$. Equation (3) indicates that a forward- looking Taylor rule takes into consideration the expected inflation and output gap when setting interest rates. In fact, under this rule the policy rate acts in response to expected variables (i.e. inflation, output gap) as opposed to lagged ones.

Castelnuovo (2003) analyses the Taylor rule taking into account interest rate smoothing using quarterly data for United States (US) and European Monetary Union (EMU). He used both the Generalized Method of Moments (GMM) and least squares to estimate forward looking rule and backward looking rule respectively.

The backward looking rule with an interest smoothing term is represented in the following manner,

$$i_t = (1-p)[\alpha + \theta\pi_{t-1} + \beta y_{t-1} + \gamma q_{t-1}] + pi_{t-1} + v_t \tag{5}$$

where p is an indicator of the degree of smoothing of interest changes, the coefficient p is assumed to lie between zero and unity. Further, large values of p are associated with a slow speed of adjustment of the interest rate to the target level. In equation (5), the interest rate responds to past period inflation, output gap and real effective exchange rate.

A forward looking rule with an interest smoothing can be illustrated as follows:

$$i_t = (1-p)[\alpha + \theta E_t\pi_{t+1} + \beta E_t y_{t+1} + \gamma E_t q_{t+1}] + pi_{t-1} + v_t \tag{6}$$

Equation (6) indicates the reaction of nominal interest rate to forecasts of inflation, output gap and the real effective exchange rate with an interest rate smoothing term.

Castelnuovo (2003) finds that the interest smoothing term enters the Taylor rule significantly. Furthermore, his results reveal that in the case of European Monetary Union

(EMU), a forward looking Taylor rule provides a better descriptive model for the interest rate path in the 1980s and 1990s. However, for the U.S there is need to consider asymmetric preferences in order to trace the policy rate path during Greenspan's tenure as the Chairman of the Federal Reserve Bank. In fact, Castelnuovo (2003) notes that a higher estimated degree of partial adjustment indicates the presence of interest rate smoothing or monetary policy inertia. The central bank may want interest rates to adjust slowly to avoid uncertainties, maintain its credibility and financial stability, as financial markets are likely to excessively react to policy changes leading to financial instability.

The final variant of the Taylor rule by Barnett and Duzhak (2008) is known as the hybrid Taylor rule. The hybrid Taylor rule presents the relationship between the policy rate, inflation, output gap and the real effective exchange rate as:

$$i_t = a_1 E_t \pi_{t+1} + a_2 y_{t-1} + a_3 q_{t-1} \tag{7}$$

where a_1 represents a coefficient of the central bank's reaction to expected inflation; a_2 is a coefficient of the central bank's reaction to the output gap and a_3 measures the central bank's reaction to real effective exchange rate. Notably, Equation (7) shows that the policy rate is set according to forward looking inflation and the lagged output gap. Barnett and Duzhak (2008) suggest that this rule is anticipated to capture the central bank's existing policy. In contrast, Bofinger and Mayer (2006) argue that the hybrid Taylor rule somehow contradicts the original idea of simple rules as a heuristic for monetary policy and should be disapproved for practical reasons.

There are several methods of estimating nonlinearity that have been proposed such as the smooth transition regression (STR) model, Markov switching and artificial neural network (ANN) methods. The ANN model fails to provide economic intuition for the nonlinear policy behavior, though Petersen (2007) suggests that it can fit the in-sample data to any degree. The Markov-switching model facilitates the modeling of non-stationarity due to abrupt changes of regime in the economy, thus it makes room for the possibility of the structural change. Van Dijk et al (2002) points out that smooth transition regression models permit for only two regimes that is from low inflation regime to a high inflation regime. In some cases researchers focus on analyzing how macroeconomic variables (i.e. inflation, unemployment rate) behave during recessions and expansions. Similarly, Petersen (2007) uses STR as it permits regression coefficients to adjust gradually from one regime to another and it gives an economic reasoning for observed nonlinear behavior.

Nonlinearities in the Taylor rule can arise in various ways. For instance, Taylor and Davradakis (2006) point out that they may result from an irregularity in the central bank's preferences or a nonlinear macroeconomic structure of the economy. Consequently, it is inappropriate to use the simple linear Taylor rule when the central banks preferences are asymmetric. Furthermore, Castro (2008) argues that a nonlinear Taylor rule is appropriate to enlighten the behavior of monetary policy when the central bank is assigning different weights to negative and positive inflation and output gaps in its loss function. Kesriyeli et al (2004), suggest that the failure to incorporate interest rate dynamics in the development of literature of nonlinear monetary policy rules may lead to model misspecification.

A number of studies show that different nonlinear time series models such as Markov-switching, artificial neural networks and smooth transition regression (STR) have been used to determine the behavior of the central banks. Swanson (1995) has utilized the artificial neural networks (ANN) nonlinear model to assess the information in the term structure due to its flexibility and simplicity. In addition, this model has performed well in various empirical applications where linear models have been unsuccessful. However, Petersen (2007) indicates that although ANN models can fit the data, they fail to give an economic explanation for the observed nonlinear behavior. Furthermore, some researchers such as Petersen (2007) have criticized the Markov-switching model on the basis that it assumes that the regime switches are exogenous and it fails to provide economic intuition behind the nonlinear policy behavior.

A smooth transition regression model[iii] is used in this paper to explain the nonlinear behavior as it enables monetary policy to evolve over time. Additionally, Cukierman (2007) points out that smooth transition regression models permit short term nominal interest rate to react marginally to expected output and inflation gaps and to adjust smoothly over the range of the reaction function. Similarly, Kesriyeli et al (2004) use the smooth transition regression model to examine the possibility of both nonlinearity and structural change in the interest rate functions of the US, UK and Germany. They find that during the 1980's there have been changes in the reaction function coefficients for the UK and US. Furthermore, the assumption of constant interest rates overtime has been criticized because it leads to model misspecification.

Following Terasvirta (2005) the standard smooth transition regression model can be derived as follows,

$$i_t = \acute{\emptyset} z_t + \acute{\theta} z_t G(\gamma, c, s_t) + u_t, \quad t = 1, \ldots., T, \tag{8}$$

and the logistic function of order one is considered as follows,

$$G(\gamma, c, s_t) = (1 + exp\{-\gamma(s_t - c)\})^{-1}, \quad \gamma > 0, \tag{9}$$

where $z_t = (\acute{w}_{t,} \acute{x}_t)'$ is the vector of explanatory variables,$w_t = (1, y_{t-1}, \ldots., y_{t-p})'$ and $x_t = (x_{1t}, \ldots., x_{kt})'$ is a vector of strongly exogenous variables. The parameters $\emptyset = (\emptyset_0, \emptyset_1, \ldots., \emptyset_m)'$ and $\theta = (\theta_0, \theta_1, \ldots., \theta_m)'$ represent $((m+1) \times 1)$ parameter vectors in the linear and nonlinear parts of the model, respectively. Furthermore, the disturbance term is iid with zero mean and constant variance, $u_t \sim iid(0, \sigma^2)$. Terasvirta (2005) shows that the transition function $G(\gamma, c, s_t)$ is continuous and bounded between zero and one and is a function of the transition variable s_t. According to Castro (2008), as the transition variable moves towards negative infinity, the transition function gets closer to zero. However, as the transition variables approaches positive infinity, the transition function gets closer to one. The transition function increases monotonically as a function

[iii] See Terasvirta (1998), van Dijk et al (2002) and Terasvirta (2004).

of s_t and the slope parameter γ indicates the smoothness of the transition from one to another and c is the location parameter that determines where the transition occurs.

A logistic STR (LSTR) model results from combining equation (8) and (9). Equation (8) permits the modeling of nonlinearities in the central bank's interest rate functions. Petersen (2007) points out that the LSTR model can best explain the nonlinear behavior because this model is able to depict economic relationships that vary in accordance with the level of the threshold variable which is inflation.

Terasvirta (2006) points out that if γ=0, the transition function $G(\gamma, c, s_t)$=0.5 and the model becomes linear. Thus the LSTR nests a linear model. However, when $\gamma \rightarrow \infty$, the LSTR model approaches a threshold regression model with two regimes with equivalent variances. From above we see there is a gap in testing the nonlinear Taylor rule in RSA

4. The Data

In South Africa, monetary policy is primarily focused at the inflation objective, thus it seeks to achieve price stability. From Feb 2000, the SARB has been adopting an inflation targeting policy, though an inflation target band of 3-6 % was set in 2002. Basically, the Reserve Bank has used the interest rate as its main tool to achieve its monetary policy goal. Interest rate changes have effects on aggregate expenditure (i.e. investment, consumption) which eventually influences the level of inflation. In the face of shocks, the Reserve bank responds by adjusting its interest rate to maintain stability within the economy. Notably, monetary policy implemented in South Africa is forward looking, as it takes approximately between 18 to 24 months for the effects of interest rate adjustment to be fully passed on inflation

The South African monetary policy went through several regimes since the early 1960's.[iv] Similarly, Aron and Muellbauer (2007), provide a brief history about the evolution of monetary policy in South Africa that indicates there were three monetary policy phases namely: liquid asset ratio system, cash reserve system and monetary accommodation. The liquid asset ratio system had quantitative controls on credit and interest rates, notably this system was used until the early 1980s. However, following various changes due to displeasure with the liquid asset ratio system, a cash reserve system was adopted. Aron and Muellbauer (2007) point that pre-announced monetary targets were utilized at the beginning of 1986, to be attained by indirectly changing interest rates. Lastly, a system of monetary accommodation was adopted in the early 1998, which used daily tenders of liquidity through repurchase transactions.

Ortitz and Sturzenegger (2007) using quarterly data examine the performance of monetary policy since 1960. They find that monetary policy has been steady, overtime it appears the South African Reserve Bank (SARB) has been placing a larger weight on inflation as it is its primary target, though the weight on output gap has been improving while there has been a less focus on the exchange rate

Firstly, we use the original Taylor rule which stipulates how the central bank can adjust its nominal interest rates in response to deviations of inflation from its target level. Furthermore, we add the US real interest to the nonlinear Taylor rule to check for the robustness of the results. Following Peterson (2007) and Castro (2008), we use a smooth transition model to examine the possible changes in monetary policy. The advantage of this model is that it offers an economic reasoning for nonlinear behavior unlike the Markov-Switching model.

In this paper, we used quarterly data from 1976:1 to 2008:4 for South Africa. The quarterly data is derived from the International Financial Statistics (IFS). The four variables that we use to estimate both the linear and nonlinear Taylor rules are the Treasury bill rate, inflation rate, output gap and the real exchange rate. The Treasury bill

[iv]For more detail, see Aron and Muellbauer(2000)

rate is the rate at which short term securities are traded or issued in the market. On the other hand, the inflation rate refers to the indices reflecting cost of acquiring a fixed basket of goods and services by an average consumer. The Treasury bill rate is used as the nominal interest rate expressed as a percentage deviation. The Inflation rate is measured by the change in Consumer Price Index (CPI) whereas output gap is derived from the logarithm of real Gross Domestic Product (GDP)[v] using the Hodrick- Prescott (HP) filter[vi]. The output gap is defined as the difference between actual output and potential output.[vii] Njuguna et al (2005) points out that it is flexible in tracing the distinctiveness of the variations in trend output. Further, this method of estimating the output gap is favored as less data is required and it gives stationary output gap over a variety of smoothing values. However, it has been criticized for its failure to give economic interpretation and it creates ambiguities.

The inflation rate is calculated by taking logarithms of the quarterly CPI index and subtracting the lagged logarithm of CPI from the current logarithm of CPI. Similarly, the real exchange rate is calculated by taking the difference between logarithms of lagged quarterly real effective exchange rate and current logarithm of real effective exchange rate. In line with Woglom (2003), we use real effective exchange rate as an approximation of the real exchange rate. Kesriyeli et al (2004) defines the real effective exchange rate index as nominal effective exchange rate adjusted for relative movements in national prices.

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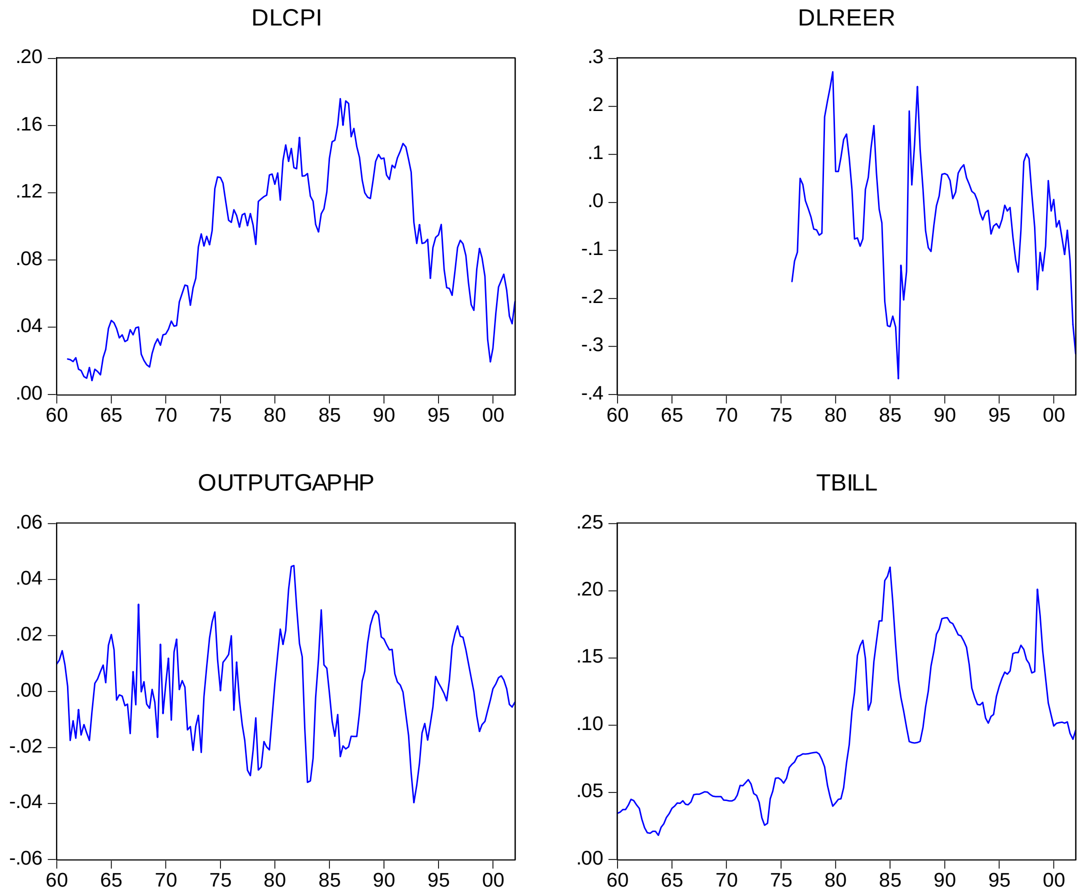
[v] See Njuguna et al (2005) for more detail.

[vi] See Sarikaya et al (2005) for a discussion on the derivation of HP Filter, its strengths and weakness

[vii] Following Nikolsko-Rzhevskyy (2009) argument of unavailability of real time data, we estimate output gap using real GDP data.

Figure 1: Plot of variables (1960Q1-2002Q1)



Notes:DLCPI-inflation rate, DLREER-real effective exchange rate, OUTPUTGAPHP-output gap derived using HP filter, TBILL- treasury bill

Figure 1 shows the series for inflation rate, Treasury bill rate, output gap and real effective exchange rate for the period from 1976:1 to 2008:4. These series indicate some volatility, with real effective exchange being the most unstable series.

Table 1: Descriptive statistics (sample: 1960Q1-2002Q1)

	i_t	y_t	π_t	rx_t
Mean	0.092	0	0.087	-0.02
Median	0.08	0	0.09	-0.018
Maximum	0.218	0.045	0.176	0.272
Minimum	0.018	-0.04	0.008	-0.367
Std. Dev.	0.052	0.016	0.05	0.117
CV	0.565	[viii]	0.526	-5.85

Notes: Std Dev-standard deviation, CV-coefficient of variation

Table 1 provides a summary of the descriptive statistics (i.e. mean, median) for the variable used in the estimation of both linear and nonlinear models. Using the coefficient of variation (CV), different variables can be compared, as it is a unit less ratio.

5. Results and Discussion

This section presents results and discussion. We will now proceed to carry out the unit root tests. Recent research studies outline various unit root and stationarity tests that can be relied upon for example, the Augmented Dickey-Filler test statistic, Ng-Perron, Elliott-Rothenberg-Stock (for highly persistent data) and Kwiatkowski, Phillips, Schmidt, Shin (KPSS 1992) stationarity test. However, in this paper we use Ng-Perron and KPSS tests. Petersen (2007) suggests that the former has exceptional size properties and KPSS test is used for robustness check of the results. Granger and Terasvirta (1993) point out that prior to using nonlinear models, it is essential to undertake a linearity test[ix]. Moreover, before the use of the linearity tests and of the STAR models, stationary time series are required. Consequently, the tables below show the results of KPSS and Ng-Perron tests.

[viii] Value is undefined

[ix] In this paper we used JMULTI package to conduct linearity tests, grid search to identify the initial values of the slope parameter and the location parameter.

Table 2: Ng Perron test results

Series	i_t	π_t	y_t	rx_t
H_0: unit root	-2.216	-1.562	-2.073	-4.860
Asymptotic critical values:1%	2.580	-2.580	2.580	-2.580
Asymptotic critical values:5%	-1.980	-1.980	-1.980	-1.980
Decision at 5%				
Reject H_0	Yes	No	Yes	Yes

Notes: i_t =interest rate; π_t =inflation rate; y_t =output gap; rx_t = real effective exchange rate

In table 2, the Ng- Perron unit root test rejects the null hypothesis of unit root for almost all the series at 5% significance level except for inflation rate. This indicates that the treasury bill, real effective exchange rate and output gap are stationary. The test indicates inflation rate variable is integrated of order one. However, we expect to find the price level to be integrated of order one and inflation rate to be integrated of order zero (i.e. I(0)). This will imply that inflation rate is stationary. These results suggest border stationarity, which some unit root tests such as Ng-Perron test cannot determine.

Table 3: KPSS stationarity test results

Series	i_t	π_t	y_t	rx_t
H_0: stationarity	0.207	0.946	0.027	0.090
Asymptotic critical values:1%	0.739	0.739	0.739	0.739
Asymptotic critical values:5%	0.463	0.463	0.463	0.463
Decision at 5%				
Reject H_0	No	Yes	No	No

Notes: $\mathbf{i_t}$ =interest rate; $\boldsymbol{\pi_t}$ =inflation rate; $\mathbf{y_t}$ =output gap; $\mathbf{rx_t}$ = real effective exchange rate

Table 3 shows that the KPSS test fails to reject the null hypothesis of stationarity for the interest rate, output gap and real effective exchange rate at 5% significance level. On the other hand, we are able to reject the null hypothesis of stationarity for inflation rate. This indicates that the inflation rate is non stationary, whereas output gap, real effective exchange rate and interest rate are stationary. The inflation rate is integrated of the order one, consequently first differencing can be used to make these series stationary. Yet, output gap, interest rate and real effective exchange rate are I(0).

5.1 Linearity Tests

The linearity test is used to determine whether nonlinearity exists within the model or not. The rejection of null hypothesis implies that a nonlinear model can be used. Furthermore, this test facilitates the determination of a transition variable and the nonlinear model (LSTR1 or LSTR2) to be used.[x] The null hypothesis of linearity can be formulated as follows, H_0: $\beta_1=\beta_2=\beta_3=0$ and the alternative hypothesis H_1: $\beta_1\neq\beta_2\neq\beta_3\neq0$. We test the null hypothesis using a LM-test regression. In fact, the asymptotic distribution obtained is chi-squared having $3h$ degrees of freedom. So, when nuisance parameters exist under the alternative hypothesis, we use a regression based on Taylor approximation expansion around the null hypothesis.

The logistic smooth transition requires a suitable transition variable to be chosen amongst competing variables. The variable with the smallest p-value (this variable has the strongest test rejection), is then chosen as a transition variable. Sarantis (1999) confirms this and recommends that one should calculate the p-values for all F tests of different equations. The better LSTR model has the lowest p-value. Granger and Terasvirta (1993) warn that strict application of this sequence of tests is likely to result in wrong conclusions being made. This possibly arises from the higher order terms of the Taylor expansion used in deriving these tests being disregarded. The results for the linearity test are presented in table 4.

Table 4: linearity test results

1976:Q2 - 2008:Q3

[x] LSTR1 represents one transition variable with one threshold value. LSTR2 represents transition variable with two thresholds.

	F	F4	F3	F2	suggested model
models without US real rates					
Transition Variable					
interest rate(t-1)	0.000	0.381	0.000	0.000	LSTR1
inflation rate	0.000	0.534	0.000	0.000	LSTR1
real effective exch	0.000	0.002	0.153	0.000	LSTR1
output gap	0.000	0.468	0.000	0.000	LSTR1
trend	0.000	0.000	0.007	0.000	LSTR1
models with US real rates					
Transition Variable					
interest rate(t-1)	0.638	0.845	0.902	0.150	Linear
inflation rate	0.000	0.380	0.005	0.003	LSTR1
real effective exch	0.013	0.574	0.076	0.006	LSTR1
output gap	0.000	0.201	0.301	0.000	LSTR1
US real rate	0.000	0.448	0.000	0.000	LSTR1
trend	0.002	0.087	0.270	0.001	LSTR1

Notes: The table presents p-values of linearity test. LSTR1 represents logistic smooth transition models with K=1.

According to table 4, the selection of the transition variable depends on p-values of the F-significance tests. Each explanatory variable stands a chance of being chosen as a transition variable. The p-values of F-statistics labeled as F2, F3 and F4 in table 4 are used to determine the number of regime shifts.[xi] If either F4 or F2 have the strongest rejection, an LSTR1 model will be recommended. Whenever the smallest p-values correspond to F3, then we can use LSTR2 to model nonlinearities. The linearity test results reject a linear model. We conclude that a nonlinear model should be used to estimate parameters using data in sampling period 1976Q2-2008Q3. The test results suggest that an LSTR1 model can be used for the full sample. The inflation rate is a transition variable in this nonlinear estimation.

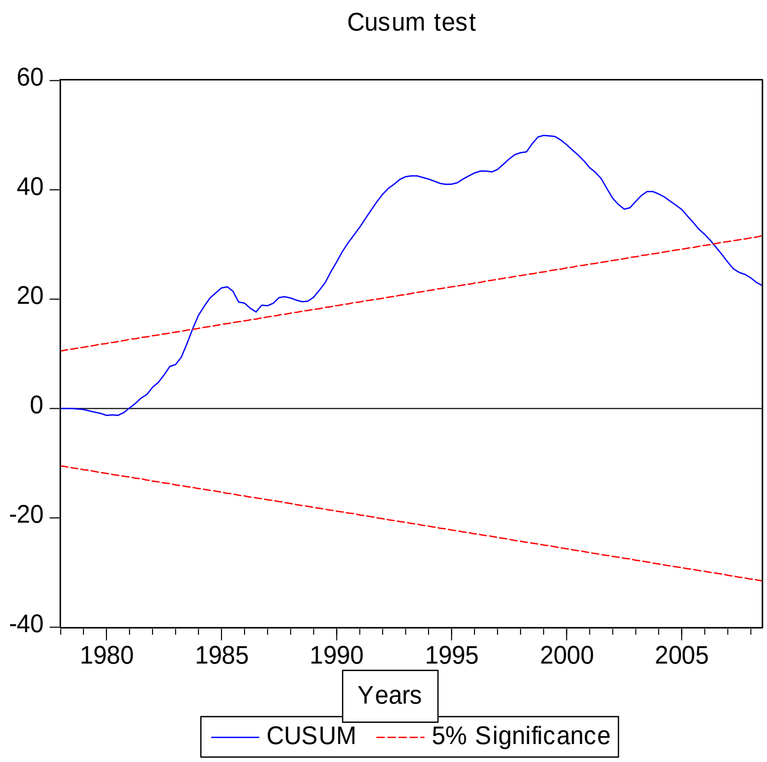
[xi] Terasvirta (2005) defined the three hypothesis namely: H_{04}: $\beta_{3=}$ 0, H_{03}: $\beta_2=0|\beta_3=0$ and H_{02}: $\beta_1=0|\beta_2=\beta_3=0$. These hypothesis defined above are referred to as F4, F3 and F2 in table 6 and other literature. This notation will be used throughout the analysis.

5.2 Parameter Stability Analysis

We have used different appropriate econometric methods to identify any structural breaks over the full sample period (1976Q2: 2008Q3). This is in line with the view of Yilmazkuday (2008) who argues that researchers should avoid relying on certain assumptions to determine the structural break dates. Instead, they should allow the data to identity such breaks. A number of techniques can be used to test for coefficient instability namely CUSUM test, CUSUM of Squares, Chow test and Recursive coefficients estimates. Woglom (2003) suggests that CUSUM test is executed on the basis of the out of sample forecasting power of the regression with estimation done over more and more sampling periods.

Following Brown et al (1975), we perform the CUSUM test for the linear Taylor rule. Initially, we assume that the parameters are constant over time, although this is highly unlikely in reality. If parameters tend to change in between two periods of time it is an indication of a structural break. We find that a structural break occurred in 1985. Nell's (2006) results confirmed the structural change and attributed it to the debt standstill. During the structural break-point, South Africa was given a debt moratorium by Western countries. This is confirmed by the results of the CUSUM test presented in figure 2. The vertical axis is unit less and the horizontal axis shows the movement of the Cusum over time.

Figure 2. Parameter test results (Cusum test)

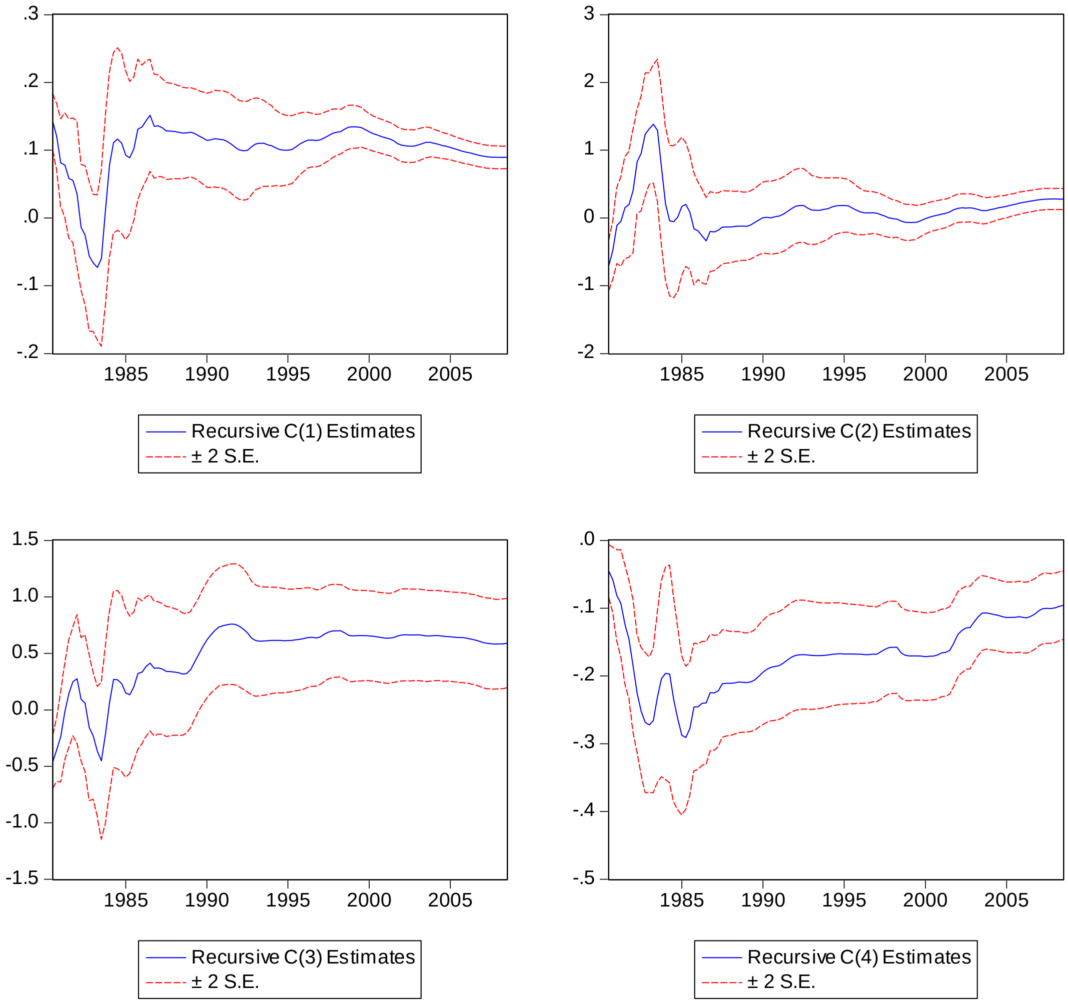


The result in figure 2 shows that the CUSUM moves away from zero and cross the confidence bands around 1985Q1. Hence, we conclude that there is coefficient instability during this period. Consequently, we have used the linear Taylor rule as the bench mark specification and smooth transition regression models to test for the existence of nonlinearities in the Taylor rule.

Figure 3, shows the recursive estimates of the simple Taylor rule.[xii] The recursive estimates of all the variables (i.e. inflation, output gap and real effective exchange) are very volatile indicating coefficient instability. The recursive estimates reveal that overtime there is a fall in the coefficient series for the constant term though the coefficient series appear to be rising before stabilizing around zero.

[xii] Recursive C(1), C(2), C(3) and C(4) represent the constant, coefficient estimate of inflation, output gap and real effective exchange, respectively.

Figure 3. Recursive coefficients estimates for Taylor's rule



Overall, there was instability around 1985 as shown in Fig 3, though thereafter the coefficients stabilized.

5.3 Estimation Results of Linear Taylor Rule

The linear Taylor rule to be estimated has a functional form shown below,

$$i_t = \emptyset_0 + \emptyset_1 \pi_t + \emptyset_2 y_t + \emptyset_3 e_t + \emptyset_4 i_t^f + u_t \tag{10}$$

where i_t is the nominal short term interest rate, $\emptyset_1$ represents the coefficient estimate of inflation rate (π_t), $\emptyset_2$ indicates the coefficient of output gap (y_t), $\emptyset_3$ denotes the estimate of real effective exchange rate (e_t) and $\emptyset_4$ represent the coefficient of foreign interest rate (i_t^f). The results of linear specification with foreign interest rate (i.e. US rate) are presented in table 5. All estimates of the coefficients of variables (except inflation rate) have expected signs and are significant at 10%.

Table 5: Taylor rule with US rate

Parameter	α	π_t	y_t	rx_t	i^f_t	i_{t-1}
Estimates	0.012	0.007	0.302	-0.013	0.140	0.864
Standard errors	0.004	0.025	0.061	0.008	0.051	0.028
p-values	0.001	0.789	0.000	0.094	0.007	0.000
AIC=-6.271		Adj R^2=0.936	DW st=1.985			

Notes: AIC-Akaike information criteria, Adj R^2-adjusted R-squared, DW st- Durbin Waston test statistic and i^f_t – foreign interest rate.

Table 6 presents results of the simple Taylor rule estimation without the US rate. The response coefficients are significant different from zero at 5% with the exception of inflation rate. These coefficients are less than one though they are significant violating the stability condition for the Taylor rule.

Table 6: Taylor rule without US rate

Parameter	α	π_t	y_t	rx_t	i_{t-1}
Estimates	0.010	0.034	0.362	-0.015	0.887
Standard errors	0.003	0.024	0.058	0.008	0.027
p-values	0.004	0.150	0.000	0.054	0.000
AIC=-6.243		adj R2=0.934	DW st=1.994		

Notes: AIC-Akaike information criteria, Adj R^2-adjusted R-squared and DW st- Durbin Waston test statistic

The results of the estimated backward looking rule represented by equation (5) are shown in Table 7. In table 7, the coefficient of all estimated variables (i.e. inflation, output gap, real effective exchange rate.) have expected signs and are significant at 5% level.

Table 7: Backward looking Taylor rule estimates

Parameter	α	π_{t-1}	y_{t-1}	xr_{t-1}	i_{t-1}
Estimates	0.041	0.681	2.025	-0.201	0.835
	(5.526)	(9.056)	(6.469)	(-6.941)	(50.039)
Reject H_0 at 5%	Yes	Yes	Yes	Yes	Yes
	DW stat=2.237		Adj R^2 = 0.914		

Notes: t-statistics are presented in parentheses. Adj R^2- adjusted R- squared and DW st - Durbin Waston test statistic. H_0: $\beta = 0$

The estimation of the forward looking rule represented by equation (6) gives the following results in table 8. The results show that all variables are significant at 5% and have expected signs. The coefficient of the lagged interest rate variable is significant at 5% level and has an expected positive sign. The interest rate smoothing coefficient of 0.869 is also large. This implies that the interest rates adjust slowly towards the targeted interest rate level.

Table 8: Forward looking Taylor rule estimates

Parameter	α	π_{t+1}	y_{t+1}	xr_{t+1}	i_{t-1}
Estimates	0.049	0.786	3.412	-0.136	0.869
	(3.731)	(6.339)	(5.733)	(-1.878)	(36.192)
Reject H_0 at 5%	Yes	Yes	Yes	Yes	Yes
	DW stat=1.563		Adj R^2 = 0.926		

Notes: t-statistics are presented in parentheses. Adj R^2-adjusted R-squared and DW st- Durbin Waston test statistic. H_0: $\beta = 0$

The hybrid Taylor rule has been estimated using equation (7) and the results are presented in table 9. In table 9, the estimates of inflation rate, output gap and real effective exchange rate enter the model with expected signs and significant at 5% level. This indicates that the behavior of interest rate can be explained by the hybrid Taylor rule. Furthermore, the estimated coefficients are not affected by serial correlation.

Table 9: Hybrid Taylor estimates

Parameter	α	π_{t+1}	y_{t-1}	xr_{t-1}	i_{t-1}
Estimates	0.010	0.142	0.264	-0.011	0.801
	(6.631)	(13.813)	(10.189)	(-3.674)	(57.416)
Reject H_0 at 5%	Yes	Yes	Yes	Yes	Yes
	DW st=2.437		Adj R^2 = 0.922		

Notes: t-statistics are presented in parentheses. Adj R^2-adjusted R-squared and DW st- Durbin Waston test statistic. H_0: β =0

Overall, the results of the backward looking, forward looking and hybrid Taylor show no signs of serial correlation as their Durbin Waston test statistic are closer to 2. Further, we use Ng Perron and KPSS stationarity to check if the residuals of the regressions of the backward, forward and hybrid Taylor rule are stationary or not. We find that the residuals are I(0) indicating that the residuals are white noise and they are stationary.

5.4 Smooth Transition Regression Model Results

The transition selection variable test results indicate that the inflation rate is the best transition variable. This is consistent with Petersen's (2007) identification of a transition variable. Petersen identifies and uses the inflation rate as a threshold variable. Equation (11) describes the model to be estimated with the inflation rate as the threshold variable. Unlike in Petersen`s model, this model includes the interest rate smoothing variable. The second version of this model uses the US real interest to control for the influence of the US interest rate on South African interest rate movement.

$$i_t = \emptyset_0 + \emptyset_1 i_{t-1} + \emptyset_2 \pi_t + \emptyset_3 y_t + \emptyset_4 e_t + (\emptyset_0 + \emptyset_1 i_{t-1} + \emptyset_2 \pi_t + \emptyset_3 y_t + \emptyset_4 e_t) * G(\gamma, c, \pi_t) + u_t \quad (11)$$

The STR models estimation results are presented in table 10 overleaf. The results show that the SARB makes a drastic change in its interest rate decision, from a low interest rate regime to a high interest regime, when inflation goes beyond the threshold level of 9.3%[xiii].

[xiii] However, this is well above South Africa's inflation target band of 3-6%.

Table 10: Estimates of STR model

		76Q2: 08Q3
	Eq.(11)	Eq.(11),US real rate
	linear model	
Constant	0.006	0.005
	(1.194)	(1.581)
Interest rate(t-1)	0.866***	0.894***
	(17.252)	(35.623)
Inflation rate	0.122*	0.056**
	(1.72)	(2.209)
Real effective exch rate	-0.028**	-0.028***
	(-2.213)	(-3.589)
Output gap	0.249*	0.201***
	(1.894)	(3.315)
US real rate		0.153***
		(3.229)
	nonlinear model	
Constant	0.027***	0.039
	(3.008)	(0.538)
Interest rate(t-1)	0.082	-0.207
	(1.418)	(-1.067)
Inflation rate	-0.319***	-0.206
	(-3.483)	(-0.410)
Real effective exch rate	0.031*	0.033
	(1.937)	(1.011)
Output gap	0.139	0.227
	(0.965)	(0.376)
US real rate		0.162
		(0.332)
γ	1629.418	192.923
c_1	0.093	0.15
AIC	-9.126	-9.207

Notes: ***, **, * represent the 1%, 5% and 10% significance level respectively at which the null hypothesis is rejected, exch represents the exchange rate . γ is the slope parameter and c_1 represents the threshold level. AIC is the Akaike Information Criteria.

The results of the estimated STR model are given in Table 10. For equation (11) without the foreign interest rate, almost all the variables namely, the inflation rate, output gap, lagged interest rate and real effective exchange enter significantly in the linear part. In the nonlinear part only the lagged interest rate is insignificant though other variables enter significantly. Notably, the real effective exchange rate has a negative sign in the nonlinear section though it enters significantly. In contrast, the estimation results of LSTR1 for the period 1976Q2- 2008Q3 with the foreign interest rate indicate that all the coefficients except for the constant enter significant in the linear part. In the nonlinear part all coefficients are insignificant. However, the F test suggests that all variables should be included in the model and therefore cannot be removed. Furthermore these models are assessed for misspecifications issues using various diagnostics checks.

We perform misspecification tests to determine whether there is an evidence of parameter non-constancy, non-normality, any remaining nonlinearity and residual autocorrelation. The misspecification test is done on residuals. The residual tests results are presented in table 11. In the first column we fail to find evidence for parameter nonconstancy or evidence for remaining nonlinearity for the full sample (1976Q2-2008Q3). Diagnostics checks findings are altered when the US real interest rate is used. There is evidence of remaining nonlinearity when the US real rate is used. Evidence suggests a nonlinear additive term should be used. This could possibly explain why the nonlinear components in the equation which contain the US real rate are all insignificant.

Table 11: Diagnostic tests

	76Q2:08Q3	
	Eq.(11)	Eq.(11),US real rate
		Residual tests
JB	0.000	0.000
ARCH(1)	1.000	0.727
AutoC(2)	0.163	0.054
AutoC(4)	0.241	0.169
		Remaining Nonlinearity : *H0 : no*
Interest rate(t-1)	0.102	0.023
Inflation rate	0.801	0.159
Real effective exch rate	0.315	0.031
Output gap	0.919	0.234
US real rate		0.004
		Parameter Constancy: *H0* :yes
H1	0.279	0.169
H2	0.826	0.438
H3	0.949	0.710

Notes: This table presents p-values of diagnostic tests for the model shown in Table 9. JB is the normality test. ARCH(1) is the LM test for first order autoregressive conditional heteroskedasticity. AutoC(2) and AutoC(4) represent the LM test of residual autocorrelation of order 2 and 4 respectively.

6 . Forecasting

We have performed out of sample forecasting to examine the performance of both the linear and nonlinear models at forecasting. Furthermore, we evaluate the economic forecast of the linear and nonlinear models to determine whether linear models provide accurate forecasts in comparison to nonlinear models. McMillan (2009) suggests that general nonlinear models are considered as being superior to depict the data, though it remains uncertain as to whether they have better forecasting ability. Similarly, Terasvirta (2006) discusses a number of reasons why nonlinear models yield inferior out sample forecasts. He argues nonlinearity does not show up during the forecast indicating nonlinear models may illustrate features in the data that do not appear frequently.

We have used a linear model as the benchmark compared to the nonlinear model without US real interest rate. Initially, equation (10) is estimated without foreign interest rate. This gives linear estimates of inflation, output gap and real effective exchange rate then forecasts are generated. Similarly, the nonlinear equation is estimated and forecasts are generated for the 12 quarter horizon. The performance of each model to successfully predict future values is evaluated through various measures such as the mean absolute error (MAE), root mean square error (RMSE), bias and Theil inequality coefficient[xiv] that are based around the magnitude of the forecast error. The Theil's U statistic has a scale that makes it lie between 0 and 1. If U=1, it implies that the predictive performance is bad. However, if U=0 it indicates a perfect fit as the actual values are equal to forecast values. The bias proportion provides a measurement of systematic error. For better results, the bias has to be closer to 0. However, a large bias indicates over or under prediction of the systematic error.

Table 12 presents forecasting results of the linear and nonlinear model. As can be seen from the results in table 12, the linear Taylor rule on all the 12 quarter horizon provides better forecasts than the nonlinear Taylor rule according to the RMSE, MAE and Theil's U. The linear Taylor rule presents the smallest RMSE, MAE and Theil's U at every horizon, though at longer horizons (2-16) it has the largest bias compared to the nonlinear model. These results indicate that the linear Taylor rule is performing better than the nonlinear Taylor rule on both shorter and longer horizons. Similarly, Clements et al (1998) point out that the empirical comparisons show that nonlinear models do not always perform better than linear models.

Furthermore, we use the Diebold- Mariano (DM) test and the Sign test, to determine the forecasting performance of the linear and nonlinear models. The DM test allows for the evaluation of the performance of two models in terms of their ability to accurately predict. The null hypothesis of the DM test suggests that the two models have equal predictive accuracy. Osterholm (2005) points out that it is a sign test that relies on the

[xiv] See for instance Osterholm (2005), McMillan (2009) and Terasvirta (2005).

absolute forecast error horizon difference of two forecasting models. With the test statistic S^i presented as follows,

$$S^i = \sum_{t=1}^{T} I_t^i \left(d_t^i\right) \tag{12}$$

where

$$d_t^i = \left|e_{nonlinear,t}^i\right| - \left|e_{linear,t}^i\right|$$

and

$\left|e_{nonlinear,t}^i\right|$ and $\left|e_{linear,t}^i\right|$ represent the absolute forecasting errors of the nonlinear and linear Taylor models respectively for h horizon at t

$$I_t^i \left(d_t^i\right) = \begin{cases} 1, & if\ d_t^i > 0 \\ 0, & otherwise \end{cases}$$

The statistic follows the binomial distribution with T and 0.5 parameters based on the assumption that the loss differential series is independent and identically distributed. Table 13 presents the Sign test in terms of p-values. The results show that we fail to reject the null hypothesis for short horizon $h1$ to $h4$ implying the nonlinear model outperforms the linear model in terms of forecasting. However, for longer horizons of more than six quarters, the sign test has smaller p-values indicating that we reject the null hypothesis of equal predictive accuracy. Consequently, we conclude that linear models perform better over long horizons as compared to nonlinear models.

Table 12: Out of samples forecasts results

	Forecast horizons(quarters)	Bias	RMSE	MAE	Theil's U
Linear Taylor rule	1	0.0006	0.0191	0.0149	0.0776
	2	0.0009	0.0192	0.0149	0.0778
	3	0.0013	0.0192	0.0149	0.0778
	4	0.0017	0.0193	0.0150	0.0780
	5	0.0025	0.0193	0.0149	0.0779
	6	0.0037	0.0192	0.0149	0.0776
	7	0.0050	0.0192	0.0148	0.0774
	8	0.0061	0.0192	0.0148	0.0773
	9	0.0075	0.0192	0.0148	0.0772
	10	0.0092	0.0192	0.0147	0.0770
	11	0.0112	0.0192	0.0147	0.0768
	12	0.0131	0.0193	0.0147	0.0766
Nonlinear Taylor rule	1	0.0006	0.0230	0.0176	0.0938
	2	0.0007	0.0231	0.0177	0.0941
	3	0.0008	0.0232	0.0178	0.0943
	4	0.0007	0.0233	0.0180	0.0946
	5	0.0009	0.0234	0.0181	0.0948
	6	0.0010	0.0235	0.0181	0.0949
	7	0.0011	0.0236	0.0183	0.0951
	8	0.0010	0.0237	0.0184	0.0953
	9	0.0009	0.0238	0.0185	0.0954
	10	0.0009	0.0239	0.0187	0.0955
	11	0.0009	0.0240	0.0188	0.0956
	12	0.0009	0.0241	0.0190	0.0958

Notes: RMSE= Root Mean Squared Error, MAE= Mean Absolute Error, Theil's U= Theil Inequality Coefficient

Table 13: Evaluation of forecasted models

Forecast horizon in quarters	Sign test(p-values)
1	1.000
2	0.500
3	0.250
4	0.125
5	0.063
6	0.031
10	0.002

7. Conclusion

Using quarterly data from 1976 to 2008 to analyse the movement of the nominal short term interest rate for the South African Reserve Bank (SARB), we find that the nonlinear Taylor rule holds. These results conclude that SARB monetary policy behavior can be appropriately described by a nonlinear Taylor rule, although other studies that left out the structural break they find that the linear Taylor rule holds. Therefore, we conclude based on the whole sample period that there is a threshold level of inflation of 9% at which the behavior of the central bank changes. This is based on a correctly specified model without the US real interest rate. However, using a sign test we find that linear models perform better than nonlinear models over longer horizon according to the out of sample forecasting. In contrast, in sample performance measures indicate that the nonlinear model performs better in terms of tracing out the data. Nonlinear Taylor rules have opened up debates on the monetary policy conduct of central banks. The monetary policy in general has become central due to the recent financial crisis. It is therefore important to incorporate financial conditions in monetary policy rule in the light of current financial crisis.

Further research should focus on including an extra nonlinear additive term on the nonlinear Taylor model which includes the US real interest rate to improve the results. The findings of this paper should be compared to those of logistic smooth transition model with two thresholds (LSTR2). This eliminates uncertainties on whether a two threshold of a transition variable (inflation) is the most appropriate approach when compared to an extra additive nonlinear term.

References

Adema, Y., 2003. *A Taylor rule for the euro area based on quasi-real time data*, Netherlands Central Bank, Research Department.

Aron, J and Muellbauer, J, 2007. Review of Monetary Policy in South Africa since 1994. Journal of African Economies Vol 16:5, 705-744.

Ball, L, 1999. Efficient rules for monetary policy. International finance,2(1): 63-83

Barnett, W.A. & Duzhak, E.A., 2008. Non-robust dynamic inferences from macroeconometric models: Bifurcation stratification of confidence regions. *Physica A: Statistical Mechanics and its Applications*, 387(15), 3817-3825.

Bec, F., Salem, M. & Collard, F., 2000. Nonlinear economic policies: Pitfalls in the Lucas critique empirical counterpart. In *Econometric Society World Congress*.

Blinder, A.S., 2000. *Central Bank Credibility: Why Do We Care? How Do We Build It?* The American Economic Review Vol 90:5, 1421-1431

Bofinger, P & Mayer, E, 2006. The Svesson vs McCallum and Nelson controversy revisited in the BWM framework. DIW Berlin, German Institute for Economic Research.

Brown, R.L., Durbin, J. & Evans, J.M., 1975. Techniques for Testing the Constancy of Regression Relationships over Time. *Journal of the Royal Statistical Society. Series B (Methodological)*, 37(2), 149-192.

Bruinshoofd, W. & Candelon, B., 2004. *Nonlinear monetary policy in europe: fact or myth?*, Netherlands Central Bank, Research Department.

Castelnuovo, E., 2003. *Taylor Rules and Interest Rate Smoothing in the US and EMU*, EconWPA.

Castro, V., 2008. *Are Central Banks following a linear or nonlinear (augmented) Taylor rule?*, University of Warwick, Department of Economics.

Clarida, R., Galí, J. & Gertler, M., 1998. *Monetary Policy Rules in practice: Some international evidence, European Review 42(6): 1033-1067*

Clements, M.P., Krolzig, H. & Michael Peter Clements and Hans-Martin Krolzig, 1998. A comparison of the forecast performance of Markov-switching and threshold autoregressive models of US GNP. Econometrics Journal Vol 1, pp. C47-C75

Cukierman, A., 2004. Nonlinearities in Taylor Rules–Causes, Consequences and Evidence. In *Keynote Lecture Presented at the 19 th Economic Annual Meeting of the Central Bank of Uruguay*.

Cukierman, A., & Gerlach, S., 2003. The inflation bias revisited: theory and some international evidence. The Manchester School Vol 71:5, 1463-6786

Granger, C.W.J & Terasvirta, T., 1993. Modelling nonlinear economic relationships. Oxford University Press, New York

Kesriyeli, M., Osborn, D.R. & Sensier, M., 2004. *Nonlinearity and Structural Change in Interest Rate Reaction Functions for the US, UK and Germany*, Economics, The Univeristy of Manchester.

McMillan, D.G., 2009. Forecasting Stock Returns: Does Switching Between Models Help? *SSRN eLibrary*.

Nell, K.S., 2006. Structural Change And Nonlinearities In A Phillips Curve Model For South Africa. *Contemporary Economic Policy*, 24(4), 600-617.

Nikolsko-Rzhevskyy, A., 2009 Monetary Policy Evaluation in Real Time: Forward-Looking Taylor Rules without Forward-Looking Data. *SSRN eLibrary*

Njuguna, A.E., Karingi, S.N. & Kimenyi, M.S., 2005. *Measuring Potential Output and Output Gap and Macroeconomic Policy: The Case of Kenya*, University of Connecticut, Department of Economics.

Olmedo, A., 2002. *Asymmetries in the Central Bank Behaviour*, THEMA (THéorie Economique, Modélisation et Applications), Université de Cergy-Pontoise.

Ortiz,A and Sturzenegger, F, 2007. Estimating SARB's policy reaction rule. South African Journal of Economics Vol. 75:4

Osterholm, P., 2005. The Taylor Rule: A Spurious Regression?*. *Bulletin of Economic Research*, 57(3), 217-247.

Petersen, K., 2007. *Does the Federal Reserve Follow a Nonlinear Taylor Rule?*, University of Connecticut, Department of Economics.

Qin, T. & Enders, W., 2008. In-sample and out-of-sample properties of linear and nonlinear Taylor rules. *Journal of Macroeconomics*, 30(1), 428-443.

Sarantis, N., 1999. Modelling nonlinearities in real effective exchange rates. Journal of international money and finance , 27-45

Sarikaya, C. et al., 2005. *Estimating Output Gap for the Turkish Economy*, Research and Monetary Policy Department, Central Bank of the Republic of Turkey.

Swanson, N.R & White, H., 1995. A model selection approach to assessing the information in the term structure using linear models and artificial neural networks. Journal of Business and Economic Statistics, 13(3), 265-275.

Taylor, J.B., 1993. Discretion versus policy rules in practice. In *Carnegie-Rochester conference series on public policy*. pp. 195-214.

Taylor, J.B., 2000. Using monetary policy rules in emerging market economies. In *Revised paper presented at the 75 th anniversary conference at the Banco de Mexico*.

Taylor, M.P. & Davradakis, E., 2006. Interest rate setting and inflation targeting: evidence of a nonlinear Taylor rule for the United Kingdom.

Terasvirta, T. & Anderson, H.M., 1992. Characterizing Nonlinearities in Business Cycles Using Smooth Transition Autoregressive Models. *Journal of Applied Econometrics*, 7, S119-S136.

Terasvirta, T., 1998. Modeling economic relationships with smooth transition regressions, in A. Ullah & D.E Giles (eds), Handbook of Applied Economic Statistics, Marcel Dekker Inc., NY, chapter 15, pp.507-552

Terasvirta, T., 2004. Smooth transition regression modelling, in H.Lutkepohl &M.Kratzig (eds), Applied Time Series Econometrics, Cmabridge University Press, chapter 6, pp 222-242.

Teräsvirta, T., 2006. *Forecasting economic variables with nonlinear models*, in A.T.G Elliot, C.Granger(ed), Handbook of Economic Forecasting, Elsevier Publisher, chapter 8.

van Dijk, D., Terasvirta, T & Franses, P.H 2002. Smooth transition autoregressive models-a survey of recent economic developments, Econometric Reviews 21:1-47

Woglom, G., 2003. How Has Inflation Targeting Affected Monetary Policy in South Africa? *South African Journal of Economics*, 71(2), 198-210.

Yilmazkuday, H., 2008. Structural Breaks in Monetary Policy Rules: Evidence from Transition Countries. *SSRN eLibrary*.

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